Advanced Gas Turbine Systems Research

**Quarterly Report
July - September 1995**

October 1995

Work Performed Under Contract No.: DE-FC21-92MC29061

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

MASTER

By
South Carolina Energy Research & Development Center
Clemson, South Carolina

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P.O. Box 880
Morgantown, West Virginia 26507-0880

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October 1995

Technical Progress Report
Advanced Gas Turbine Systems Research
Cooperative Agreement DE-FC21-92MC29061

July 1, 1995 - September 30, 1995

SUMMARY

Major Accomplishments and Reports issued by AGTSR during this reporting period:

- 93, 94 continuation amendments and 95 proposal negotiations completed
- Received summary of research accomplishments from 23 AGTSR projects
- Conducted interest survey for 32 AGTSR research projects with IRB
- Organized poster session and university-industry panel for ATS Annual Review
- Co-organized AGTSR's 1st technical retreat on combustion instability at Penn St.
- Prepared white paper review by IRB on unsteady stage interactions preproposal
- Prepared white paper review by IRB on wave rotor mini-consortium concept
- AGTSR endorsed Univ. of Houston's Advd.Tech. Program on GT heat transfer
- Began coordination with Iowa State and Duke on internat'l gas turbine program
- Participated on GTA's first Allied Interest Forum on gas turbine R&D
- Wrote and distributed AGTSR's fifth newsletter to DOE, IRB, and members
- Site visit to Oak-Ridge Labs to review facilities and plan materials workshop
- Oak-Ridge materials users program announced to AGTSR performing members
- Updated AGTSR fact sheet for FY96 reflecting 32 research projects
- 93 semi-annual progress reports distributed to METC and IRB
- 94 first annual progress reports distributed to METC and IRB
- Completed 93, 94, 95 proposal inventory for 155 proposal submissions
- AGTSR education paper accepted for publication and presentation at FIE'95
- ATS-AGTSR technology matrix completed and coordinated with DOE-METC
- Site visit to MIT and Northeastern to review heat transfer research and facilities
- Hosted DOE Site Inspection of AGTSR program at SCERDC
- Submitted AGTSR report for inclusion in the 1996 IGTI Technology Report
- Distributed new combustion instability proposals to IRB to review research plan
- Won \$61K EPSCOR proposal that leverages AGTSR's industry intern program

Negotiations were conducted in July-August, 1995 for the nine new research projects added to the AGTSR Industry/University Research Consortium. The nine new projects have either an August 1 or September 1, 1995 start-date. The NEPA's for these new projects have also been completed. As recommended by the Industry Review Board (IRB), University of Wyoming's project on high turbulence internal heat transfer was terminated. Their final report is due by the end of October, 1995. MIT, Central Florida, and Michigan State were programmatically one-year efforts, but the IRB recommended that their projects be continued with new, follow-on efforts starting in September, 1995.

For the ATS Annual Review, October 17-19, 1995, AGTSR organized a poster session for the 31 AGTSR research projects. Also, an Industry-University panel was assembled with two representatives from the IRB and two from universities to discuss the effectiveness of the AGTSR research consortium. An update on AGTSR performance will be presented at this review meeting -- the formal review paper and abstract have been submitted to METC for inclusion in the proceedings.

AGTSR organized their first technical specialty meeting at Penn State University, September 11-12, 1995. The topic was combustion instability in lean, premixed combustion systems. Twenty-seven R&D experts from industry, universities, and government attended. These types of specialty meetings will continue on an as-needed basis in other subthrust research topic areas.

On August 7, 1995, AGTSR participated in GTA's first Allied Interest Forum to discuss gas turbine R&D, marketing and regulatory issues. SCERDC/AGTSR just became an affiliate member of GTA. The forum was held at the Crystal Marriott in Crystal City, VA.

On August 28, 1995, SCERDC had a U.S. DOE Site Inspection at Clemson, SC to review the AGTSR program. Several influential visitors from D.C. attended: Barbara Wainman - Assistant to the Chairman of the Interior Appropriations Committee - U.S. House of Representatives, Ann Cecchetti - Director of Government Liaison - U.S. DOE, Bob Kripowicz - Deputy Assistant Secretary for House Liaison - U.S. DOE, and Charles Roy - Financial Systems Officer - U.S. DOE. All seemed pleased with the program review and came across as proponents of the AGTSR consortium.

During this period, AGTSR updated their DOE Fact Sheet incorporating FY95 activities and the nine new projects joining the program, distributed AGTSR's fifth newsletter where a summary of the new projects with points of contact was provided, and updated the AGTSR technology description for the 1996 IGTI Technology Report.

In 1993 and 1994, AGTSR received cost-sharing contributions of \$25,000 from each of the IRB members. All six IRB companies have paid their 1995 IRB fee. GE just paid their FY95 dues on August 7, 1995. The IRB now consists of six U.S. turbine engine manufacturers, with EPRI and GRI continuing to act as utility and industrial gas turbine advisors for AGTSR.

Western Michigan University has joined the AGTSR program during this period. Currently, 79 universities are members of AGTSR, representing 36 states. Northwestern and Kansas State University have recently expressed interest in joining the program.

Membership

During this reporting period, Western Michigan University was added as an AGTSR Performing Member. AGTSR membership is now at 79 schools, representing 36 states. Saginaw Valley State University requested information to join last quarter, but have not yet responded. Northwestern and Kansas State University have recently expressed interest in joining the program. Other recent members include Polytechnic University in New York, and Northeastern University in Massachusetts.

Parker Hannifin attended our recent combustion instability meeting at Penn State and have expressed continued interest in joining AGTSR, possibly in FY96. They are still interested in Dual-Fuel issues which will be a likely research topic in future RFP's.

In August 1995, IRB invitation were sent to Howmet and PCC (two coating companies). Note that both Howmet and PCC are part of ATS with support for materials research from DOE-HQ's and Oak-Ridge. They have not yet responded formally, but mentioned to me that they are very much interested and will probably decide by the end of October, 1995. An IRB Letter of Invitation was recently mailed to the R&D department of the Long Island Lighting Company, who are interested in combined-cycles and advanced, low emission gas turbine combustor concepts -- they have not yet responded, and I will follow-up next quarter on their decision.

1993-1994-1995 Subcontract Progress

AGTSR has finished the amendment packages to continue 22 of the 23 existing projects into follow-on yearly extensions. The University of Wyoming, initially a one-year effort, was not recommended for renewal by the IRB. This project will terminate this summer with the final report due in October, 1995. The subcontract agreements for the nine new projects approved in FY95 have now been negotiated, with the exception of Syracuse University and MIT. These two schools do not agree with AGTSR's publication approval policy -- instead they would like a "prior comment period" to review publications as opposed to a "approval policy." This issue is currently being worked between CURF and DOE/METC. The nine new subcontracts will have start-dates of either August 1 or September 1, 1995. The first annual progress reports have now been received for the thirteen 1994 subcontracts. The executive summaries of these reports have been distributed to respective technical experts and R&D managers within METC and the IRB. The annual reports for the 1993

awards are due October 31, 1995. The new 1995 projects will have their first semi-annual progress reports due the end of March, 1996.

In order to determine the extent and continuance of IRB interest in the 23 existing projects and the 9 new awards, AGTSR requested the IRB to rank all ongoing research contracts in an interest survey. Four of the six IRB companies have now completed this survey. The other two firms should respond shortly. AGTSR will consolidate the results and report back to METC next quarter.

AGTSR's Third Combustion Workshop

The third AGTSR Combustion Workshop will be hosted by UC-Irvine and will take place in Lake Arrowhead, CA, March 19-22, 1996. This workshop will be organized in a more informal format -- a "Gordon-style" approach will be used to review and discuss DOE sponsored combustion research activities. Industry and government personnel actively working on combustion R&D for lean-premixed systems will be invited. The first announcement for this workshop should go out by the end of November, 1995. This combustion review meeting is being coordinated with the PI, Scott Samuelsen, at UC-Irvine.

AGTSR's First Technical Specialty Meeting

AGTSR recently organized their first specialty technical retreat on combustion instability. This retreat was hosted by Penn State University, September 11-12, 1995. This first such retreat was motivated by the need to bring university and industry researchers closer together in certain subthrust topics of a technical discipline -- in this case, combustion instabilities in lean, premixed systems. The intent is to have a higher level of interaction focusing just on the specialty topic, in contrast to workshops which are wider-scoped in their review. Additional retreats covering other specialty topics within the heat transfer, aerodynamics, and materials areas will be considered on an as-needed basis. The specialty meeting at Penn State resulted in an important action item: industry experts in combustion instability agreed to review the experimental design, modeling, and prediction capability set forth in the new AGTSR proposals with the intent to mesh specific research/experimental deliverables with industry needs. This is a positive step in maintaining closer collaboration with AGTSR combustion researchers on a regular basis.

ATS Materials Workshop

The ATS Materials Workshop is scheduled for February 12-14, 1996 in Charleston, SC. This workshop will be co-hosted with DOE Headquarters, DOE-Oak Ridge and Energetics. A technical organizing committee has been established that consists of DOE, SCERDC, university and industry members to define the detailed agenda, covering topics such as coatings, material degradation and lifetime prediction models, casting/alloy development, ceramics, and new emerging material concepts beneficial to the ATS program. The first workshop announcement has already been distributed by AGTSR, and a second one will shortly be sent by Energetics. The detailed technical agenda with registration material should be available by mid-November, 1995.

AGTSR Endorses Oak-Ridge Lab's User Program

In July 1995, AGTSR visited the High Temperature Materials Lab (HTML), Oak-Ridge, TN to begin coordination on the ATS Materials Workshop. AGTSR was impressed with their experimental research capability and professional technical staff doing in-house materials research. AGTSR was particularly impressed with the HTML User Program and have shared this information with AGTSR performing members to encourage them to take advantage of this superb resource and research opportunity.

The User Program provides industry and university researchers access to an array of special research equipment needed to characterize the microstructure and microchemistry of materials and to investigate their physical and mechanical properties. HTML staff members are available to work with the users, train them, assist in research, and analyze and interpret results. There is usually no-fee associated with nonproprietary research.

First-rate experimental research equipment consists of items such as Scanning and Transmission Electron Microscopy, Scanning Probe Microscopy, Energy-Dispersive Spectroscopy and Electron Holography that has been used to study various catalyst materials for combustion-catalyst systems, eg., palladium nanocrystals. HTML has research centers established in X-Ray Diffraction, Residual Stress, Physical and Mechanical Properties, Ceramic Machining and Manufacturability. They also have a Laser Flash Thermal Diffusivity Apparatus that may be used to measure the thermal conductivity and investigate thermal aging of a ceramic thermal barrier coating.

Industrial Interns Finish-Up

The AGTSR Industrial Intern program began in June, 1995 and finished near the end of August, 1995. This program was highly recommended by the IRB. A total of thirteen applications were received and based on industries review and evaluation, six interns were selected to participate in the eight-week long program. Three interns from UC-Irvine were targeted for Solar Turbines, AlliedSignal, and P&W. An intern from Carnegie Mellon went to GE-Corporate R&D, another from Central Florida joined Westinghouse - Orlando, and an intern from VPI joined Allison Engine Company in Indianapolis. All interns were graduate students and the intern from Carnegie Mellon was a post-doctorate student. The interns were paid a weekly stipend of \$450 dollars per week. AGTSR received positive feedback from industry and interns and plans are to at least double the number of interns in fiscal year 96. Some constructive comments were to expand the program from 8-weeks to 10-weeks, distribute applications much earlier in the year, and provide an allowance of \$1000 per intern to absorb dislocation expenses when traveling to the sponsoring company site. Applications for FY96 interns should be distributed to AGTSR members by December, 1995.

GTA's First Allied Interest Forum

AGTSR recently became an affiliate member of the newly established Gas Turbine Association (GTA). GTA had their first allied interest forum in August, 1995 where they discussed gas turbine education and research needs, regulatory issues, and domestic and overseas marketing concerns. AGTSR was invited to give a briefing and talked about the uniqueness and benefit of the AGTSR consortium, major R&D issues applicable to land-based gas turbines, and a case study showing the transition of fundamental heat transfer research to an industry's new product design for low-pressure turbines. AGTSR reinforced the position that consortia are critical to nurturing collaborative R&D and multidisciplinary engineering education.

White Paper on Multi-Stage Aero-Interactions

Clemson University and NASA-Lewis approached AGTSR about forming a mini-consortium dedicated to a unique design capability that accounts for multi-stage interactions in compressors and turbines. Their idea was put forward in a white paper and submitted to the IRB for review.

All the IRB have considered the white paper and they all support the idea and believe that accounting for stage interactions would have a positive influence on current design practices. Since funding is limited, the IRB recommended that they compete their white paper with other proposal ideas in the FY96 RFP solicitation.

White Paper on Wave Rotors

NASA-Lewis Research Center approached AGTSR to see if we were interested in leveraging their in-house Wave Rotor research to potentially benefit ground-based power systems by topping the cycle with a wave rotor. Internally the wave rotor is an unsteady flow device that shows a lot of promise for small to moderate-size gas turbine systems. NASA is committed to a practical demonstration of the wave rotor concept by the year 2001. NASA's concept and preliminary analyses have been distributed to the IRB. Only P&W has responded so far -- they are not interested in pursuing this concept for their commercial gas turbine systems. The Wave Rotor packet from NASA was also distributed to DOE/METC for review and information.

Miscellaneous Activity

During this period, AGTSR conducted three site visits: MIT, Northeastern University, and Clemson. MIT's and Northeastern's visit was done jointly with GE-Lynn, Dave Kercher, a heat transfer expert for GE. AGTSR and GE reviewed MIT's rotating internal heat transfer facility and ABB's first-stage cooling experiment on MIT's unique blowdown facility, in support of ATS Phase II. Their internal cooling experiment is supported by AGTSR and consists of an experimental portion using a 2-D PIV set-up, and an computational approach to model the heat transfer and viscous flowfield. At Northeastern, an AGTSR performing member university, we reviewed their advanced film-cooling research supported by GE and their internal cooling rotating facility that uses liquid crystals to measure surface heat transfer. We also reviewed a unique turbine concept patented by Professor Gorlov of Northeastern University -- this concept uses a helical turbine as a breakthrough technology to harness low-head hydro and wind power, and is supported by DOE and New England Power Company. At Clemson, AGTSR reviewed the computational, advanced film-cooling research conducted by Professors Leylek and Liburdy. In just one-year of AGTSR support they have written five papers on their new film-cooling

predictive methodology in support of industry. The IRB has also reviewed their research and are very pleased with their approach and overall progress.

AGTSR recently got a paper accepted for publication and presentation at the FIE'95 Engineering Education Conference in Atlanta, November, 1995. This paper will review the education mission of AGTSR and highlight the Industrial Internship and Fellowship programs, and in particular discuss the feedback of the first group of interns that finished this summer.

With METC, AGTSR coordinated a technology matrix chart that will depict research program ties with university and industry partners. This matrix should prove very useful in identifying research needs and facilitating the coordination and transition of research results and innovative design concepts to industry.

AGTSR recently won a \$61K South Carolina EPSCOR proposal to initiate an undergraduate industrial internship gas turbine program for Clemson University and the University of South Carolina. This program will leverage the use of AGTSR's Industry Review Board and will reinforce AGTSR's newly started internship activity on a national basis.